Research Seminar

Tianjin University of Technology

辅助康复机器人感知控制

Advanced Sensing and Control of Assistive/Rehabilitative Robots

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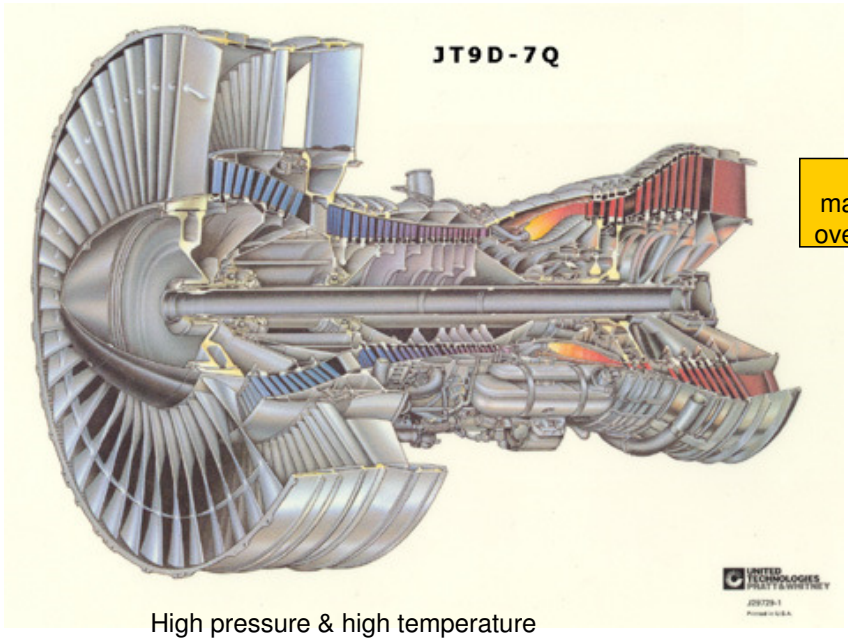
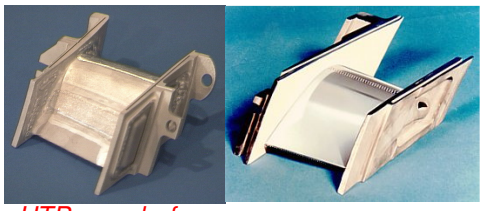
Advances in Factory Automation

Aero Engine High Pressure Turbine (HPT) Airfoil Overhaul



High pressure & high temperature operating environment up to about **1900F & 190PSI**



HTP vane before & after blending

Repair, maintenance & overhaul (MRO)

Compressor blade before & after blending

HPT blade before & after Blending

Untethered Wall Climbing Robot 无拴线爬壁机器人

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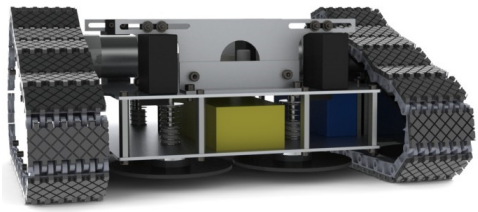
INVERT ROBOTICS



6 person team, 6 hour inspection process with safety concern → 1 operator, 0.5 hour inspection, operating outside tank

Powered Assistive Exoskeleton

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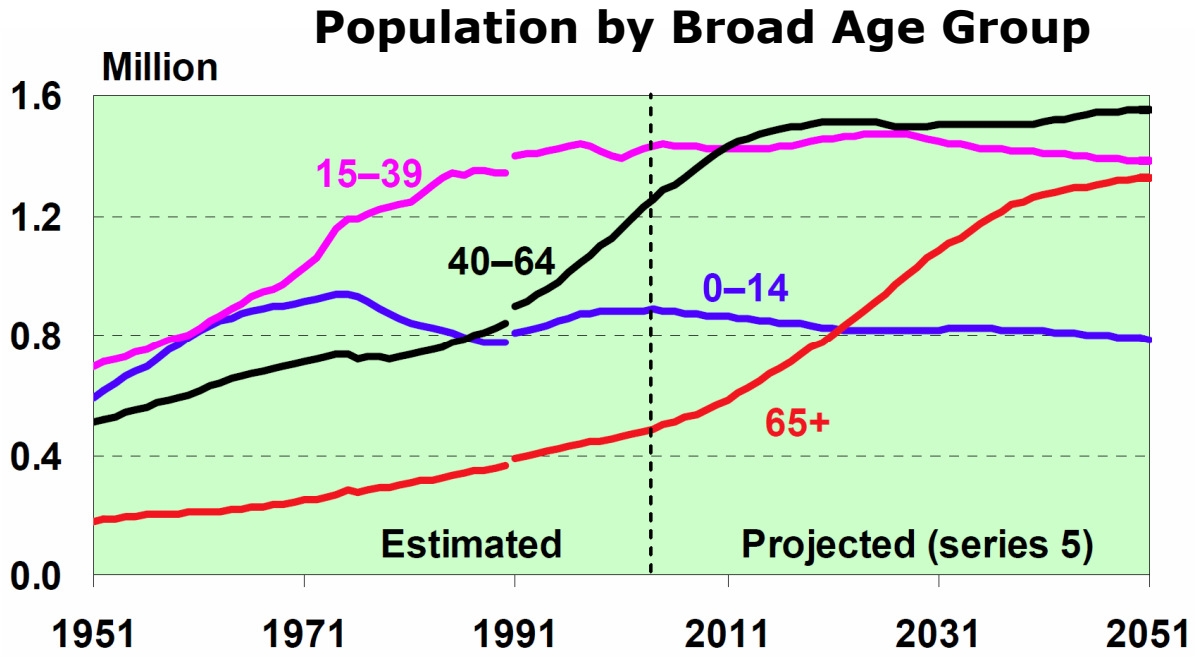
提纲

- 背景介绍
- 外髋节系统，肌电传感器
- 气动人工肌肉和模糊控制系统
- 实验
- 结论

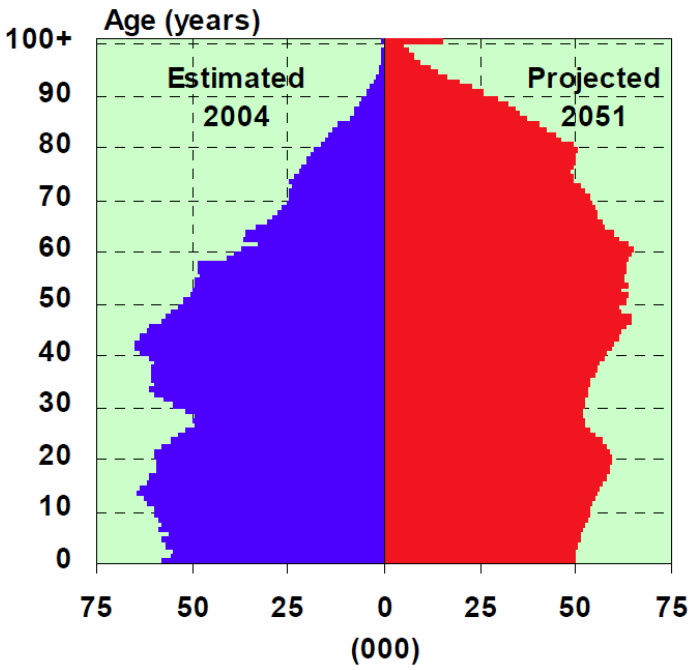
Motivation-Ageing Population



Demographic Aspects of New Zealand's Ageing Population, March 2006 .

Motivation-Ageing Population

Age Distribution of Population



Demographic Aspects of New Zealand's Ageing Population, March 2006 .

Motivation

- Cost of intensive medical care
  - **6000/yr (NZ), 2/3 will require rehabilitation**
  - **$25000/person**
- Decrease recovery time- constant usage
- Better form of assistance for lower limb
- Other possible application where force augmentation is necessary

Motivation-Advancements in Technology

Motivation-Improvement on current form of assistance

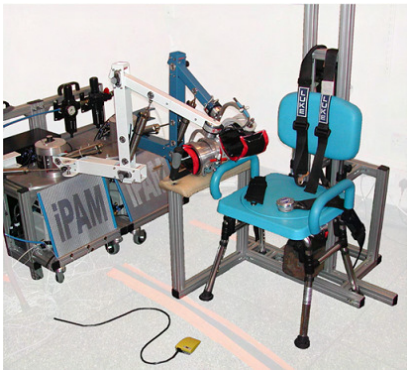
Motivation - Other possible applications





Upper Limb Assistive Devices

ARMin: Tobias Nef et al.(2007)



iPAM: A. Jackson et al.(2007)

MIT-MANUS: Hermano Igo Krebs et al.(2007)

Upper Limb Assistive Devices - UC Arm Skater, Chen XQ (2009)

- Min force: 4N
- Max force: 22.5N
- Force delivered omni-directionally
- Accurate force control, limited by omni wheel slip

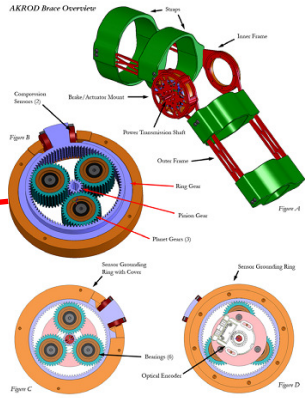
Lower Limbs - Related Work

- Michigan state university, Daniel P Ferris et al- Ankle foot Orthosis
- Delivers force to ankle joint for plantarflexion and dorsiflexion
- The study aimed to analyze if mechanical assistance at the ankle joint would reduce the metabolic cost level for steady speed walking-Result it does but not significant enough because of the recoil action of the Achilles tendon.
- The study was mainly concerned with in house testing of the effects of powered exoskeleton on human gait.

Daniel P. Ferris et al.(2008)

Lower Limbs - Related Work

- Active Knee Rehabilitation Orthotic Device(AKROD)- Northeastern University
- Electro-rheological fluid in the knee joint provides variable resistive damping to assist in knee control during swing
- Limitation- Does not provide torque to the joint but rather active dampening

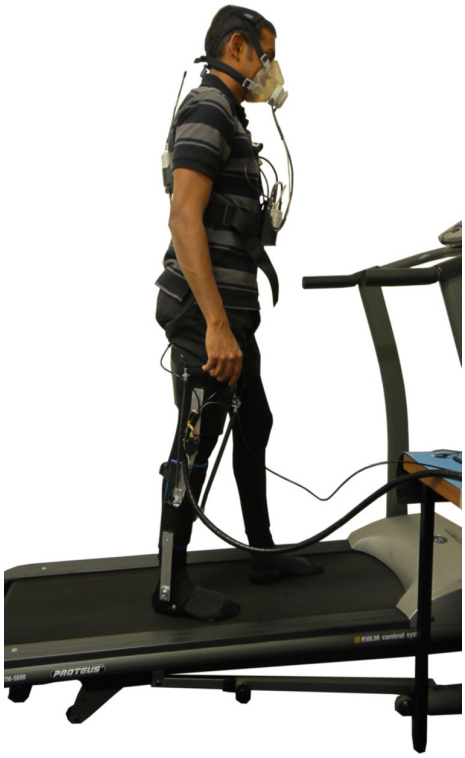


Weinberg B et al.(2007)

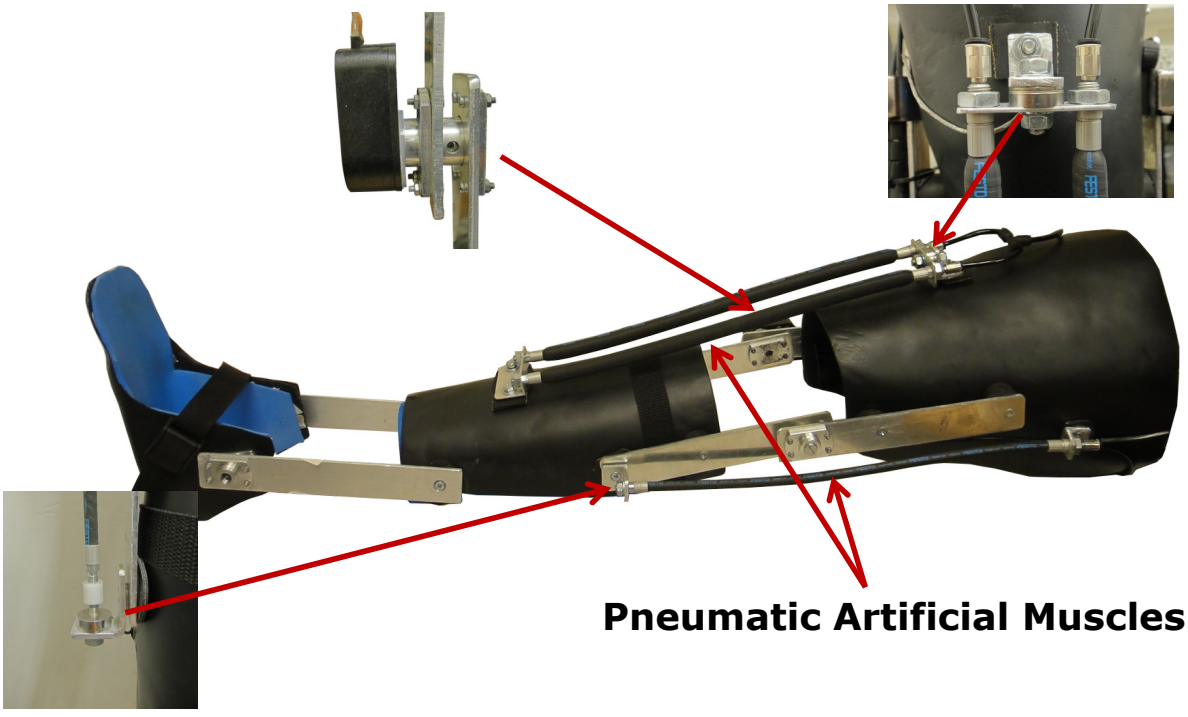
Objectives

- An active lower limb exoskeleton for assistance and rehabilitation
- Pneumatic Artificial Muscles (PAM) for actuation
- Using control signals derived in real time from the user- Surface electromyography (sEMG) and joint kinematic information
- Augment the force produced by the user's skeletal muscle

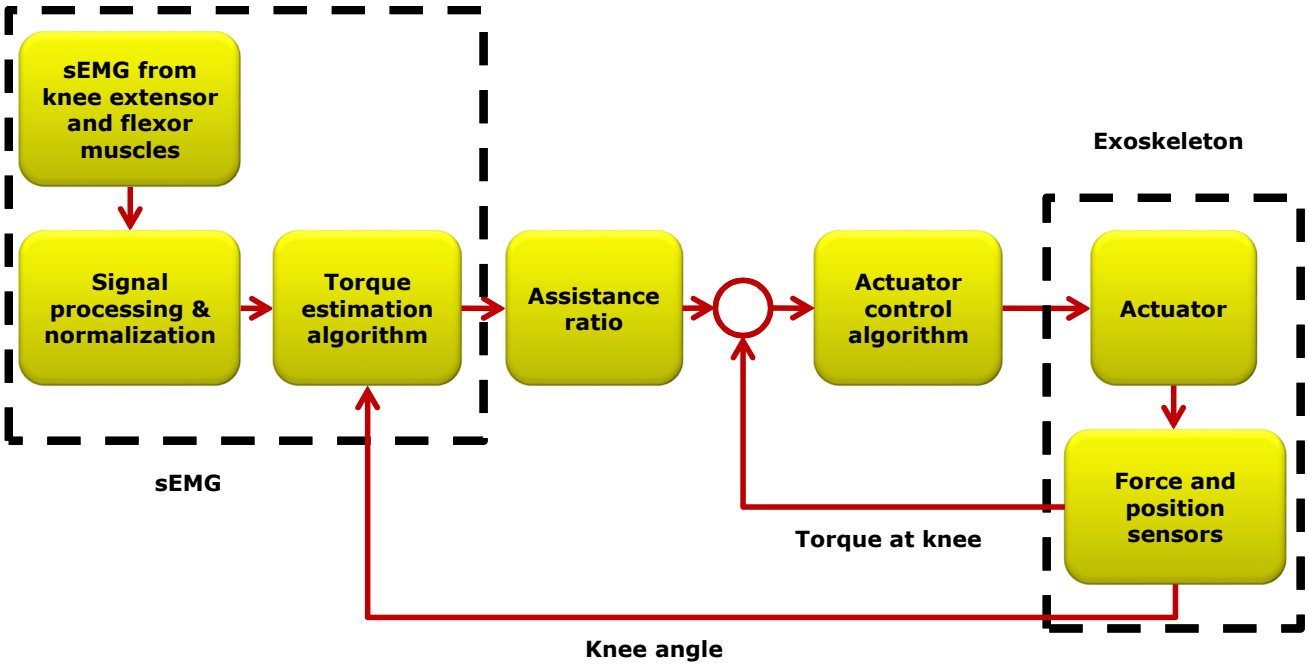
Prototype



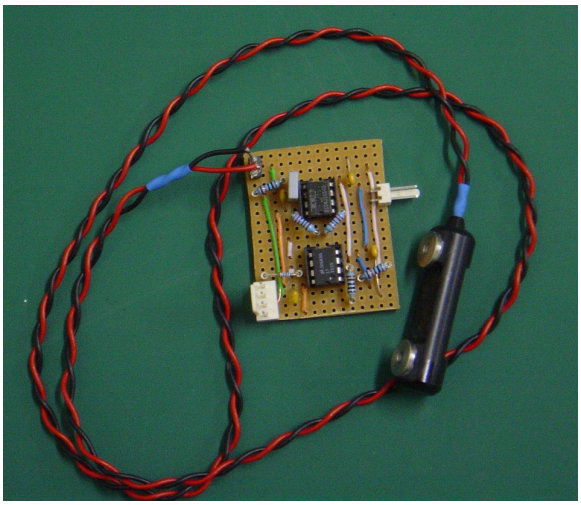
Exoskeleton hardware-Prototype



Exoskeleton System Overview

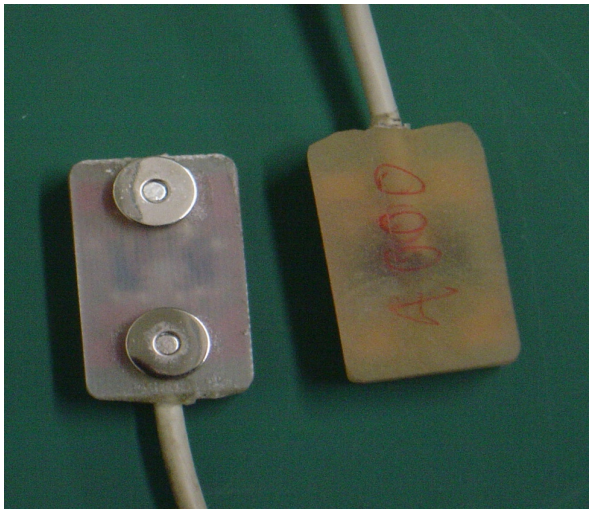


sEMG Electrode

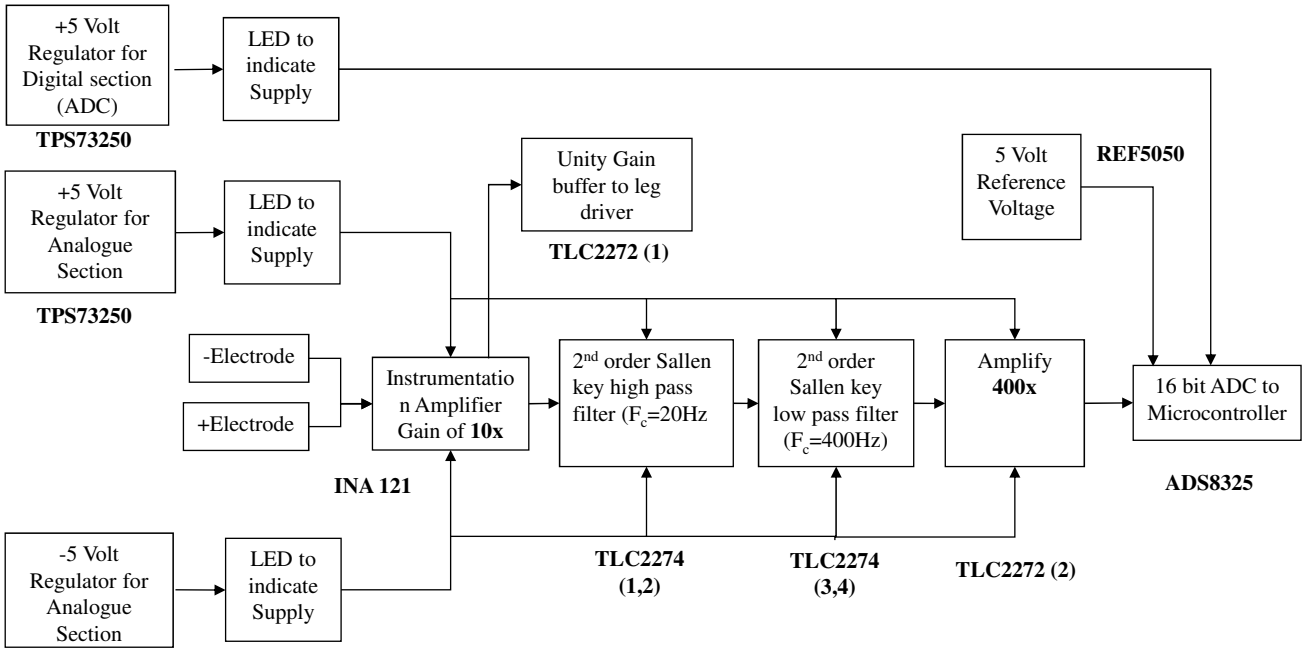


Initial Prototype

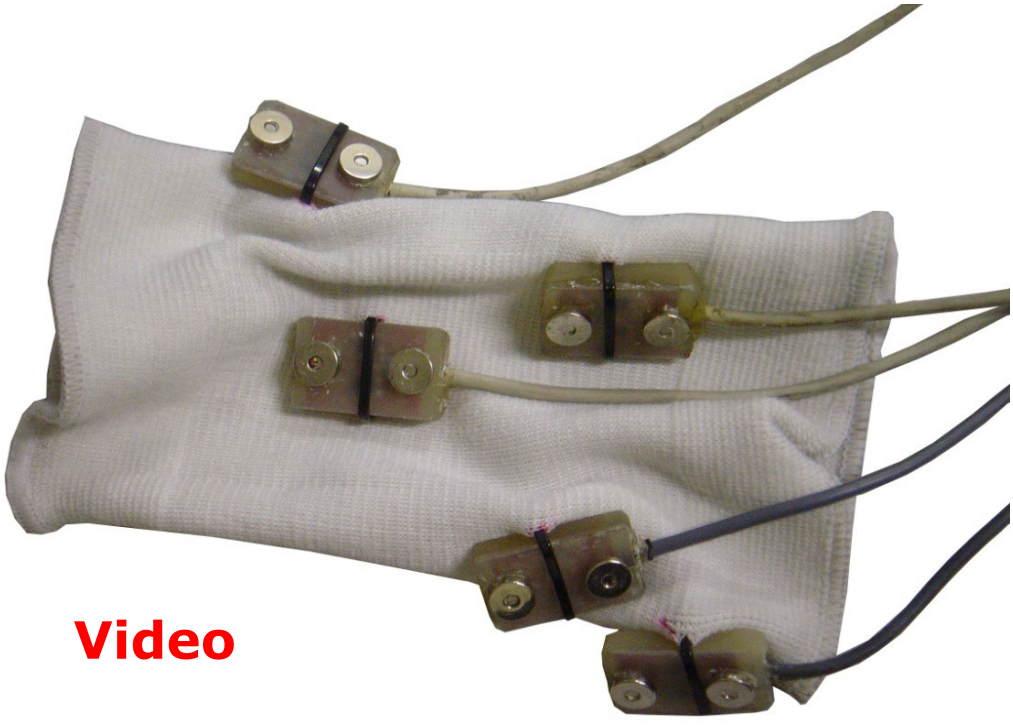
Final design



sEMG Signal Conditioning - Block Diagram



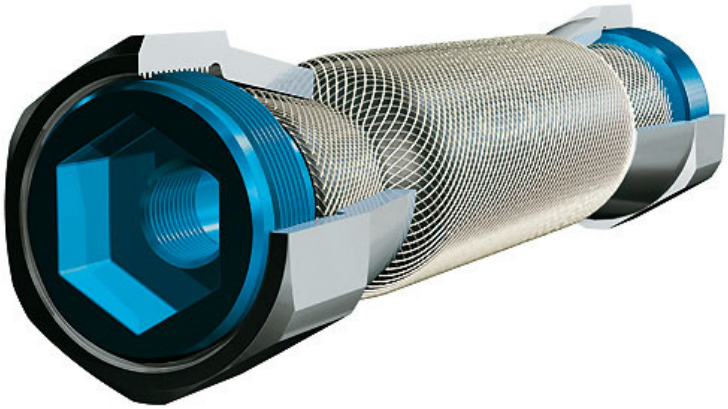
sEMG System



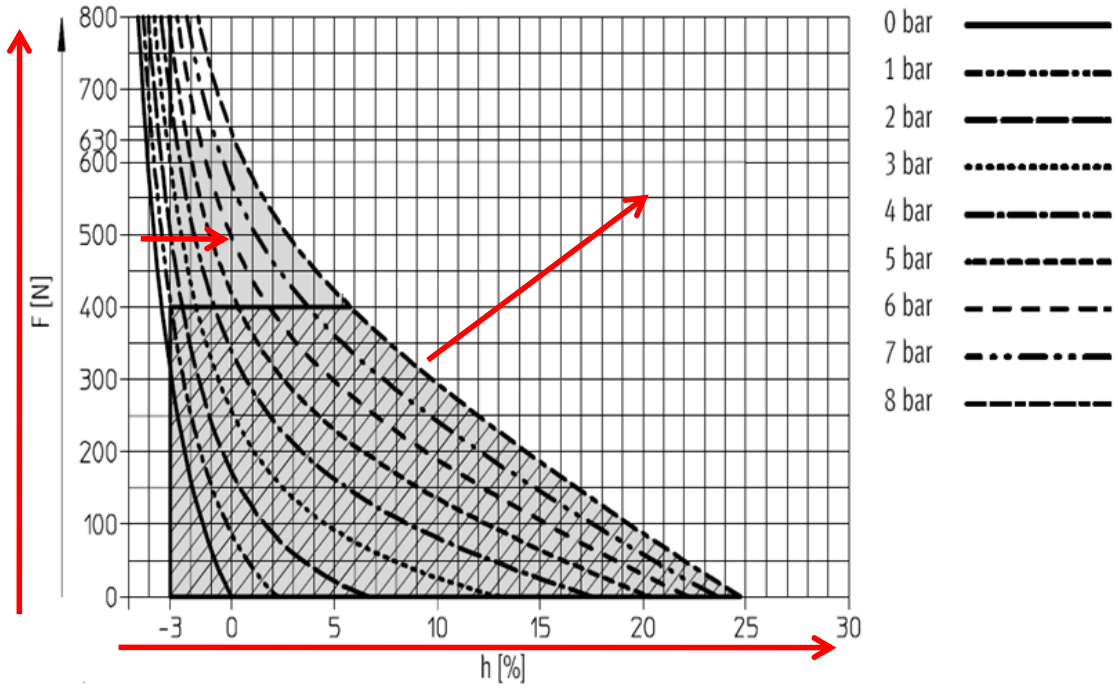
Video

Actuation-Pneumatic Artificial Muscle (PAM)

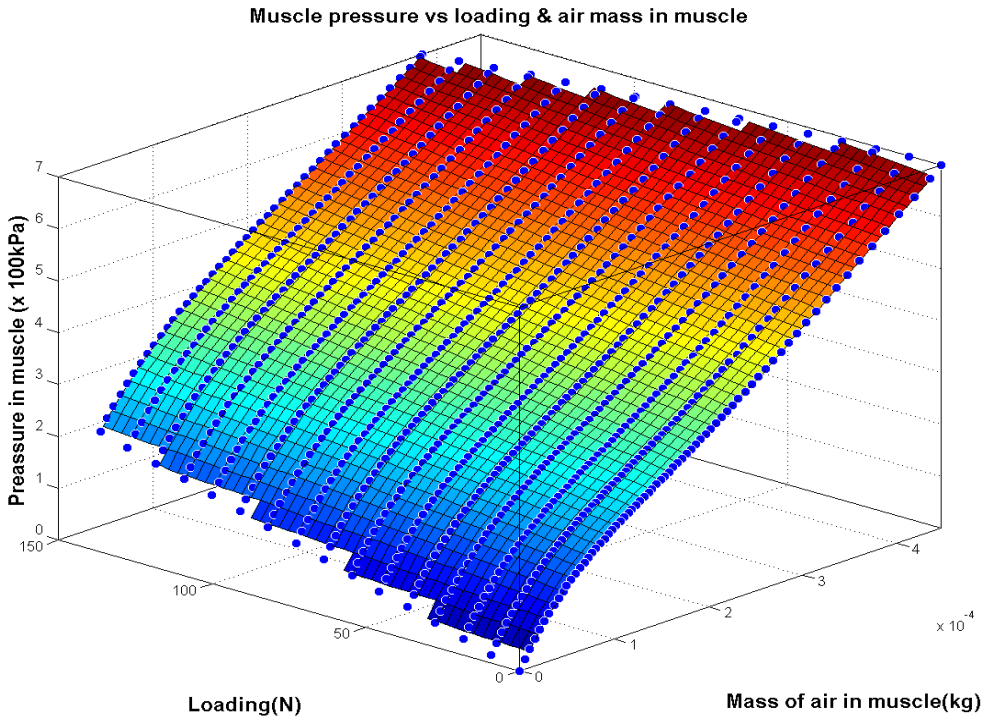
- Classical model: mesh angle
- Lumped mass model: Nonlinear spring & damper
- Characteristic look up table



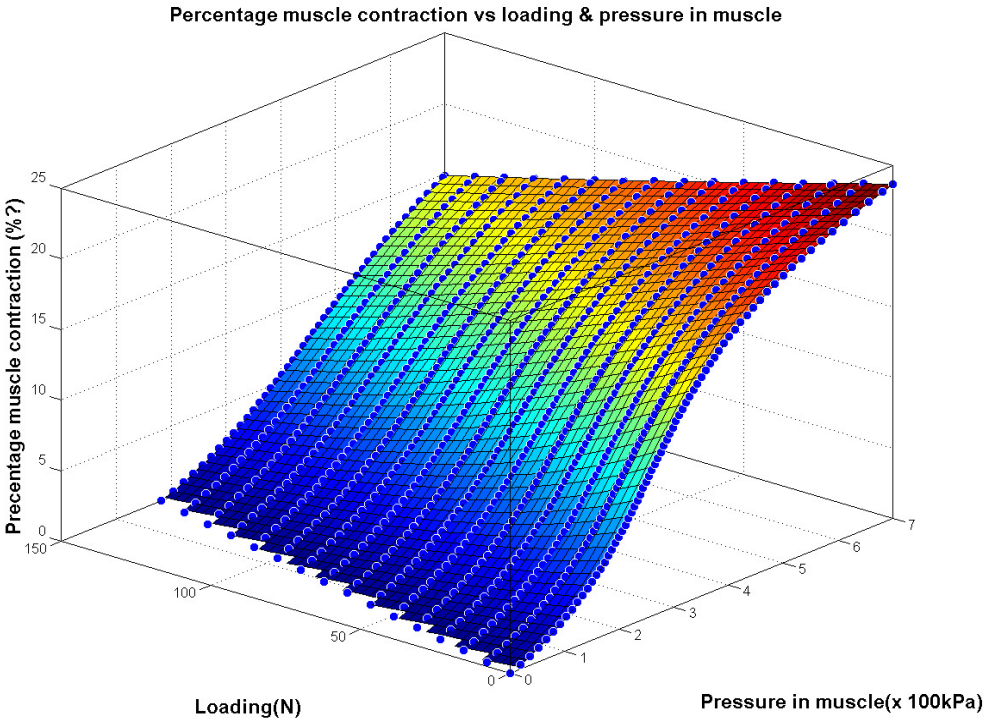
PAM Characteristics



PAM Modeling- Characteristic Surface



PAM Characteristic Surface

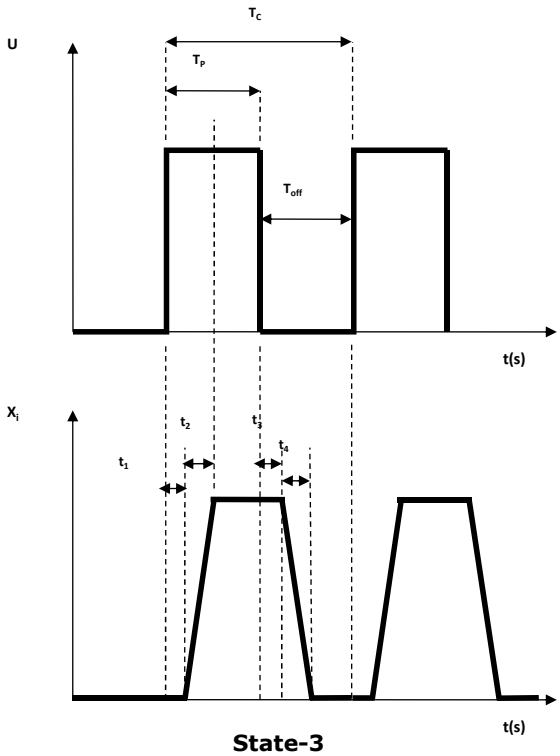


Mass flow rate of air

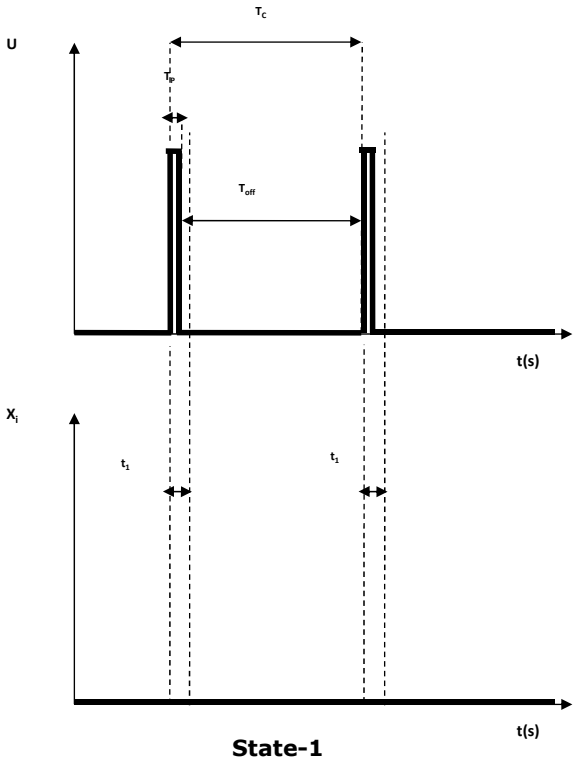
$$\dot{m} = \begin{cases} C_f A_V C_1 \dfrac{P_u}{\sqrt{T}} & if \ \dfrac{P_d}{P_u} \le P_{cr} \\ C_f A_V C_2 \dfrac{P_u}{\sqrt{T}} \left(\dfrac{P_d}{P_u}\right)^{\kappa^{-1}} \sqrt{1 - \left(\dfrac{P_d}{P_u}\right)^{\frac{\kappa-1}{\kappa}}} & if \ \dfrac{P_d}{P_u} > P_{cr} \end{cases}$$

$$C_1 = \sqrt{\frac{k}{R}\left(\frac{2}{\kappa+1}\right)^{\frac{\kappa+1}{\kappa-1}}} \quad C_2 = \sqrt{\frac{k}{R}\left(\frac{2}{\kappa+1}\right)} \quad P_{cr} = \left(\frac{2}{\kappa+1}\right)^{\frac{\kappa}{\kappa-1}}$$

High Speed valve

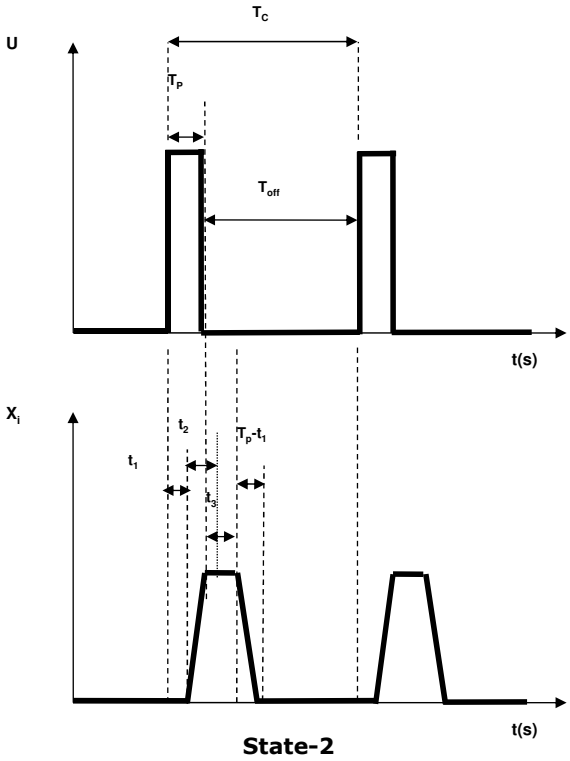


State-3

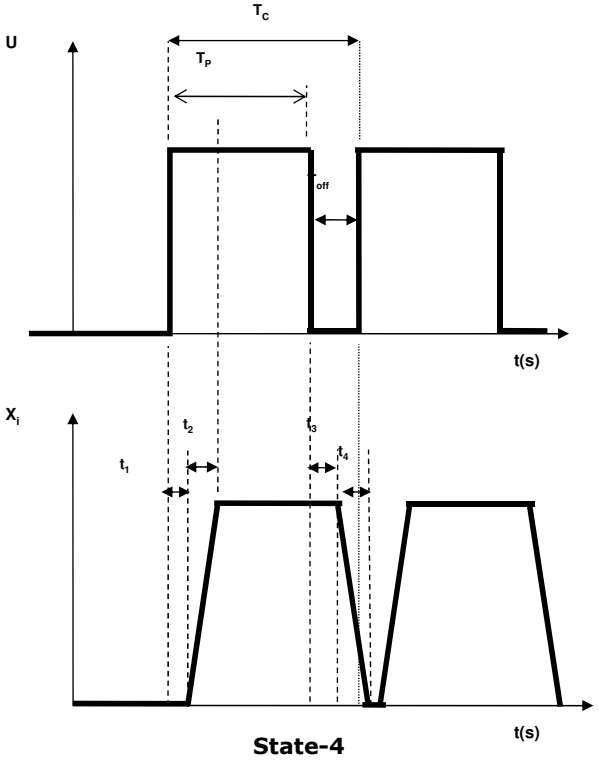


State-1

High Speed valve

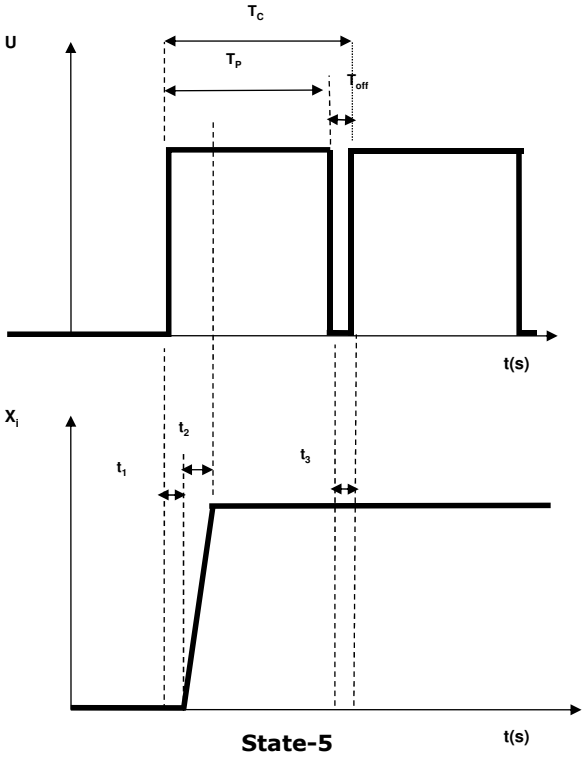


State-2



State-4

High Speed valve

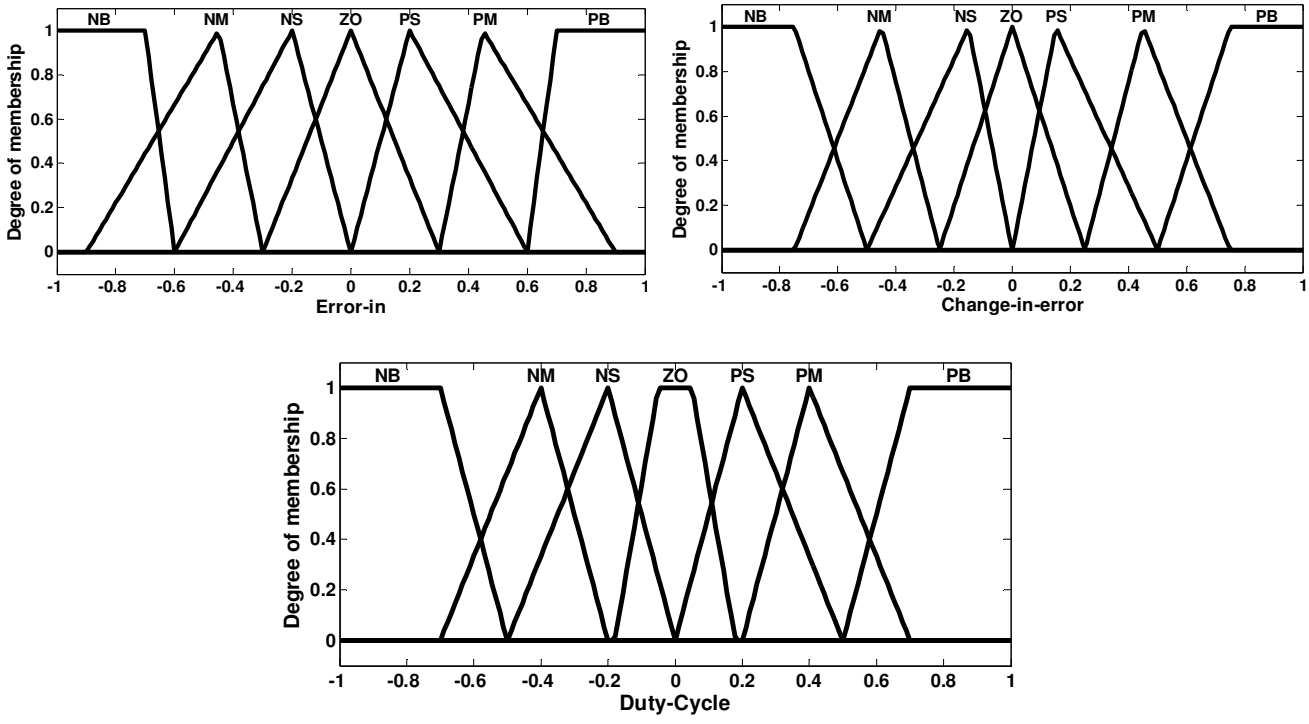


State-5

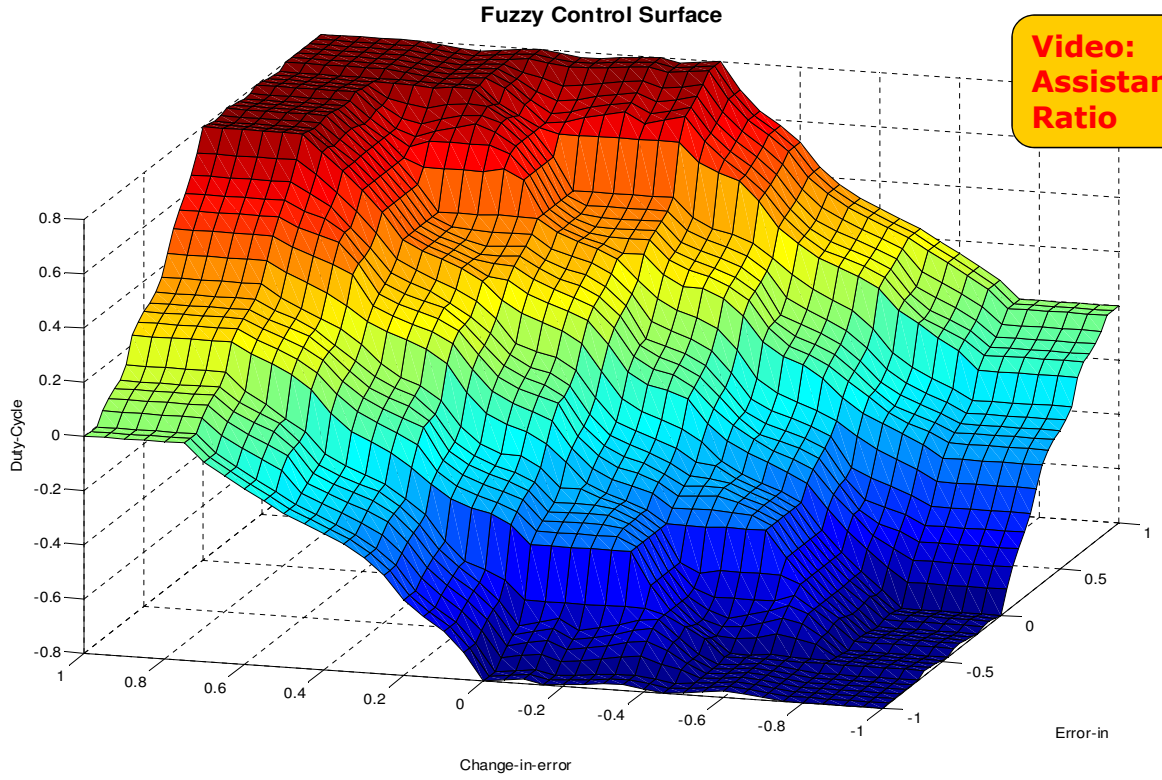
Fuzzy Logic Control

- Efficient Nonlinear Controller
- Model-less Controller
- Ability to compensate for variation and noise
- Existing knowledge from literature can be used in rule base
- Performance comparable to model based controller

Fuzzy Control-Variables

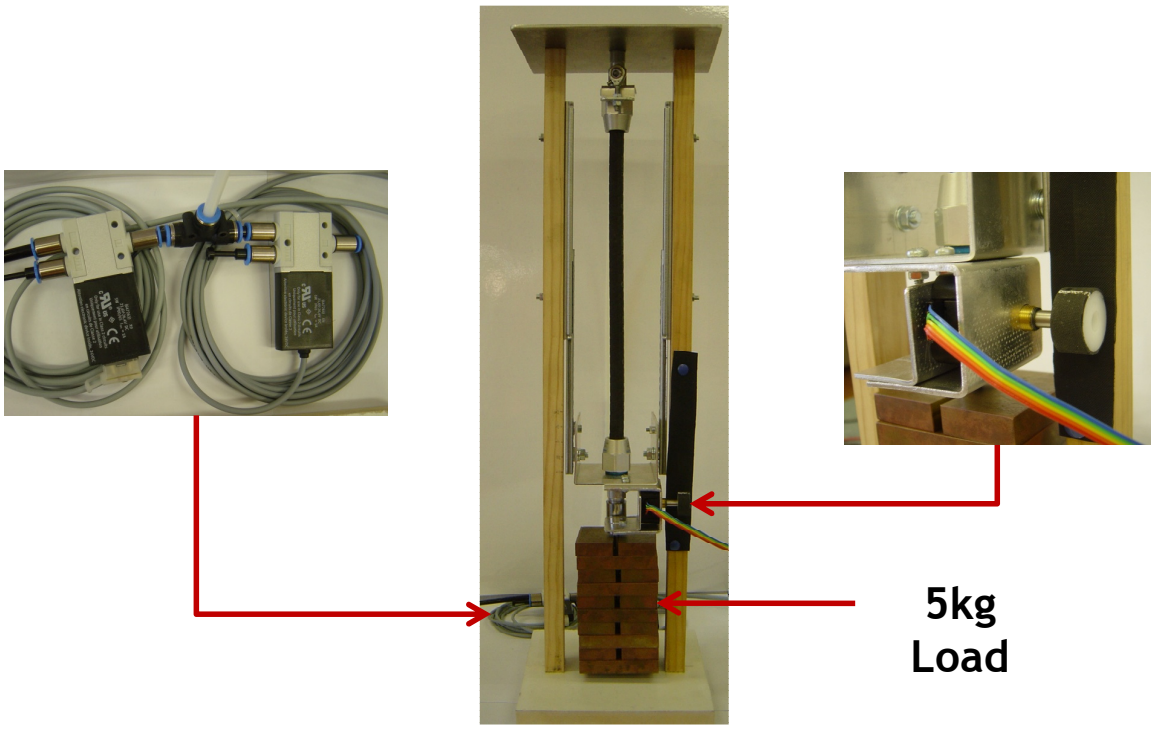


Fuzzy Control Surface

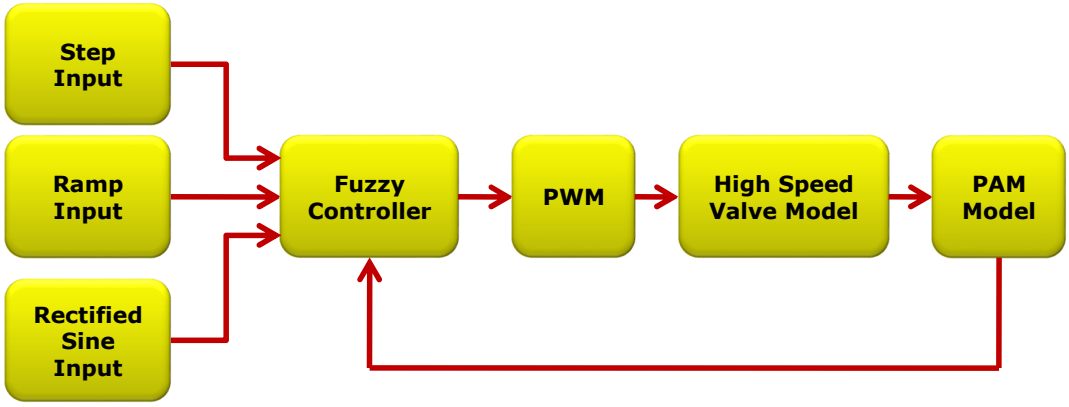


Video: Assistance Ratio

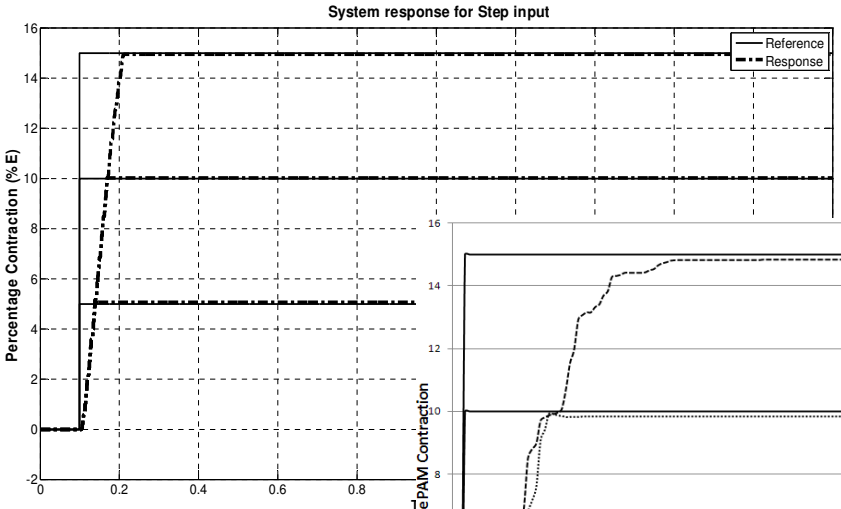
Experimental Setup



Simulation Setup

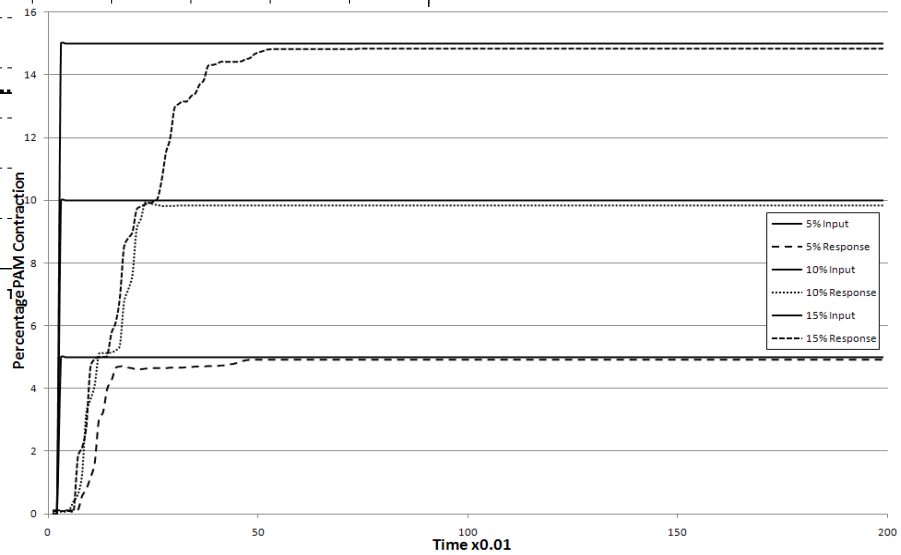


Results-Step Input

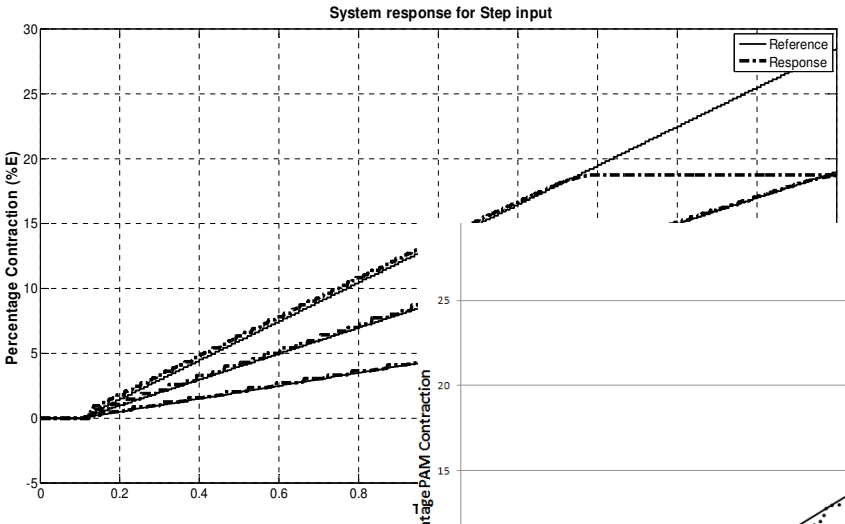


Experimental Results

Simulation Results for 5%,10% and 15%

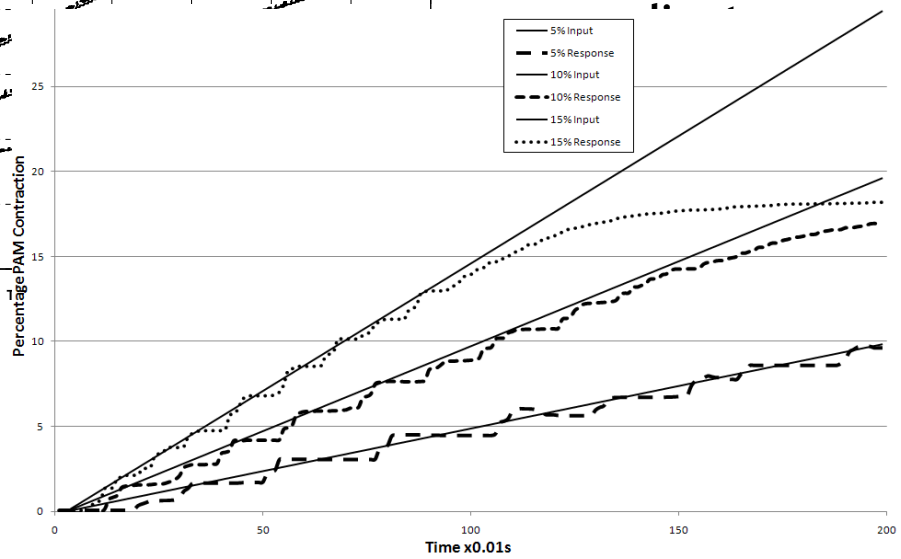


Results-Ramp Input

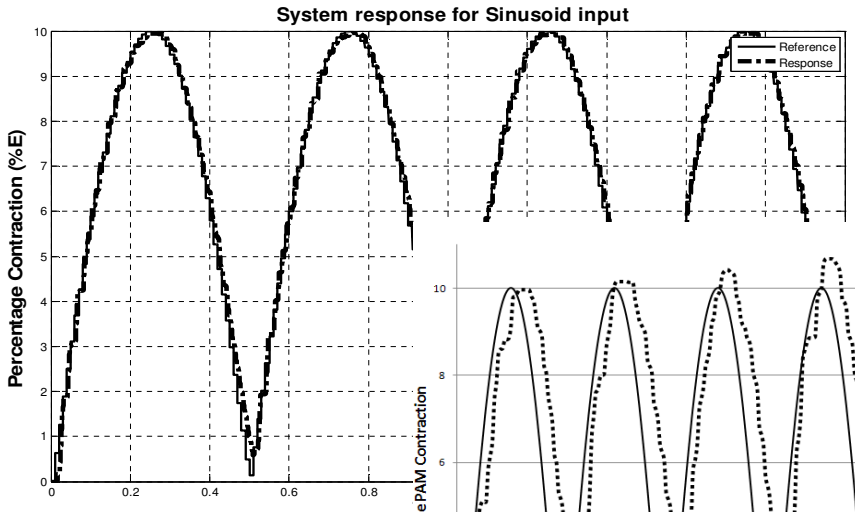


Experimental Results

Simulation Results for 5%,10% and 15%

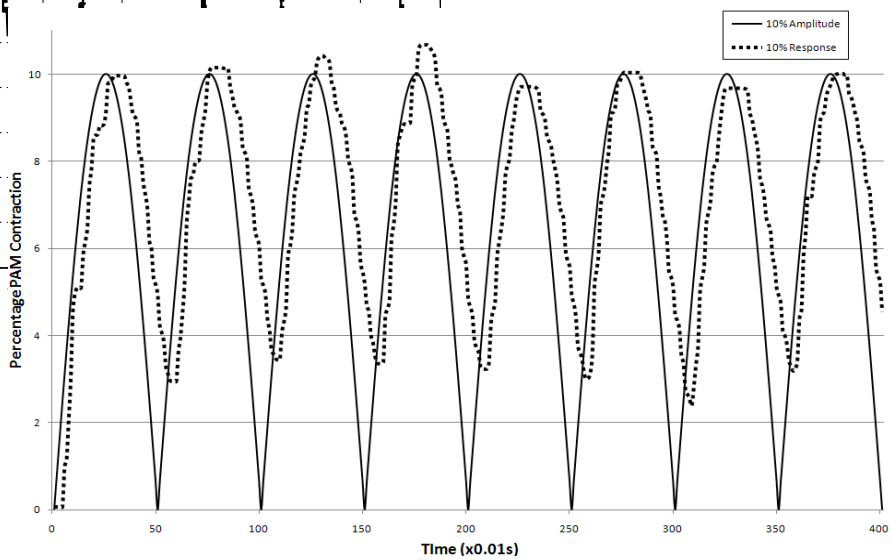


Results-2Hz Sine Input

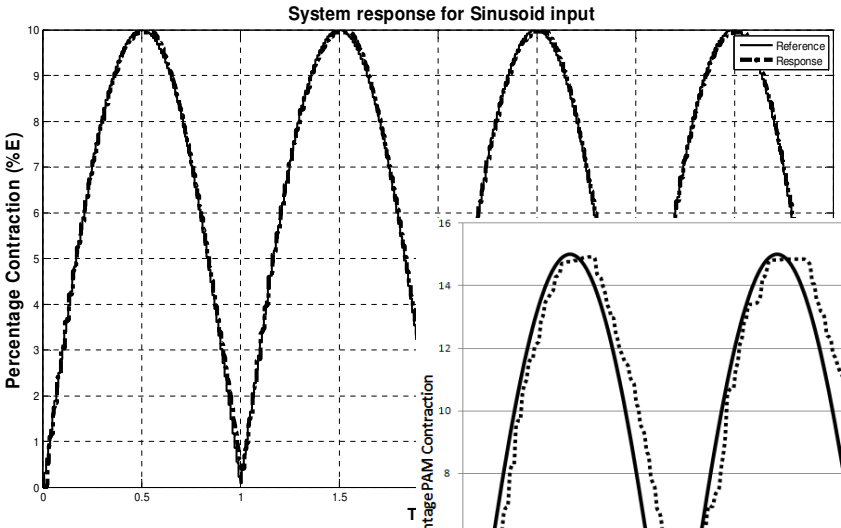


Experimental Results

Simulation Results for 10% contraction

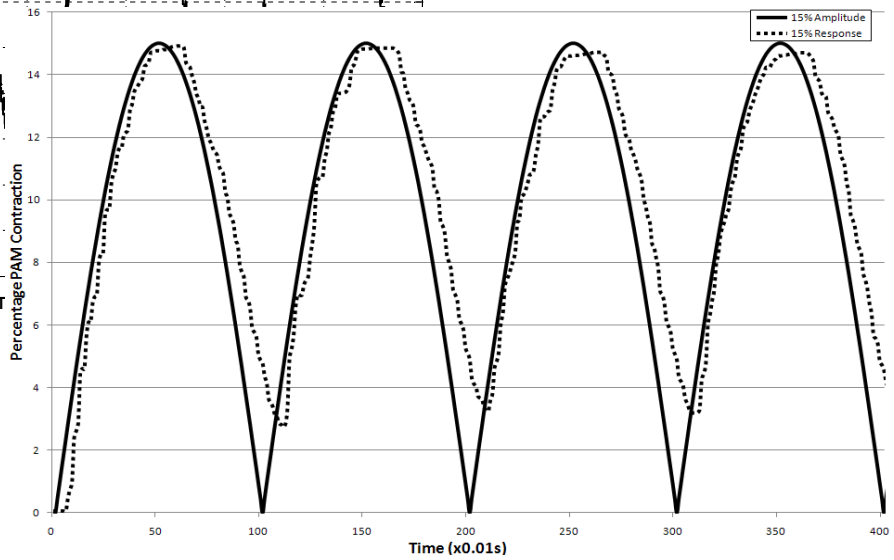


Results-1Hz Sine Input



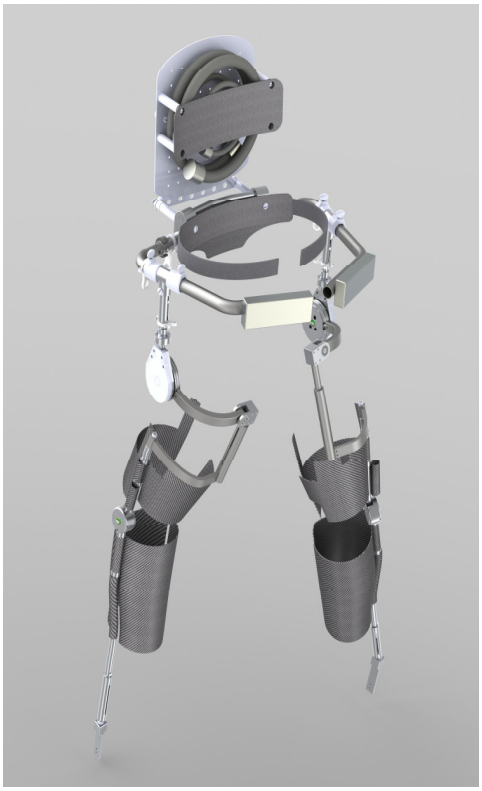
Experimental Results

Simulation Results for 15% contraction



Mark II: a lower limb exoskeleton

- Rehabilitative device for both medical and non-medical settings to assist the users leg muscles
- Aimed at people with walking difficulties but able to support themselves
- Encompasses ankle, knee and hip joints of both legs
- Actuation of knee and hip provided by pneumatic artificial muscles (PAM's)



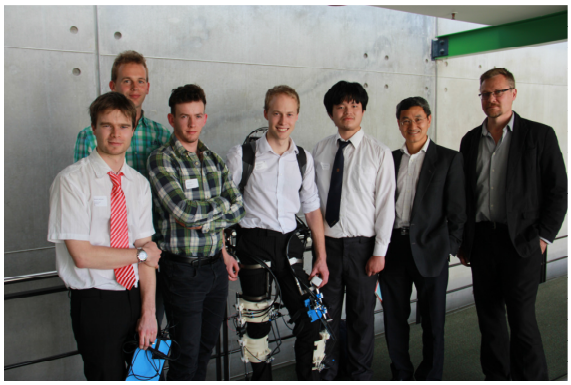
Mark III: Soft exoskeleton velcro structure

Tightly in place; 2x PAM (pneumatic artificial muscle)

Conclusion

- Extract and process sEMG
- Design a soft exoskeleton
- Design self-organized fuzzy logic controller
- Validate controller performance
- Integrate the sEMG and controller into the exoskeleton

Acknowledgement



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  - Kelsey Paterson
  - Liam Ellis
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- Intern: Vincent Groenhuis, University of Twente, Netherland
- Grant: KiwiNet
- Industry sponsor: Festo (New Zealand)

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